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(54) **METHOD AND SYSTEM FOR VISUALIZING A CORRELATION MARK USING AN ELECTRONIC DEVICE**

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G06K 9/52	(2006.01)
G06T 5/00	(2006.01)

(52) **U.S. Cl.**
CPC . *G06K 9/46* (2013.01); *G06K 9/52* (2013.01);
G06T 5/00 (2013.01); *G06K 2009/4666*
(2013.01); *G06T 2201/0051* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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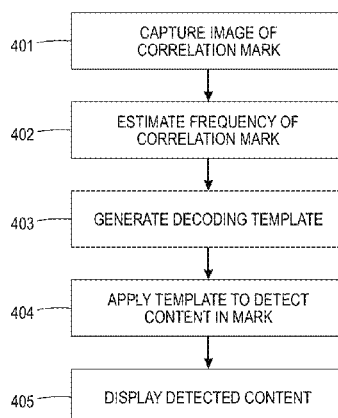
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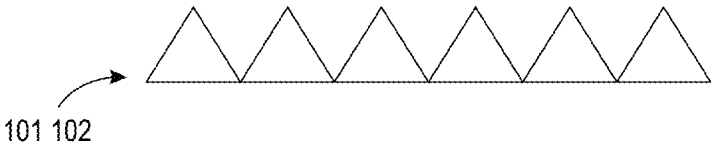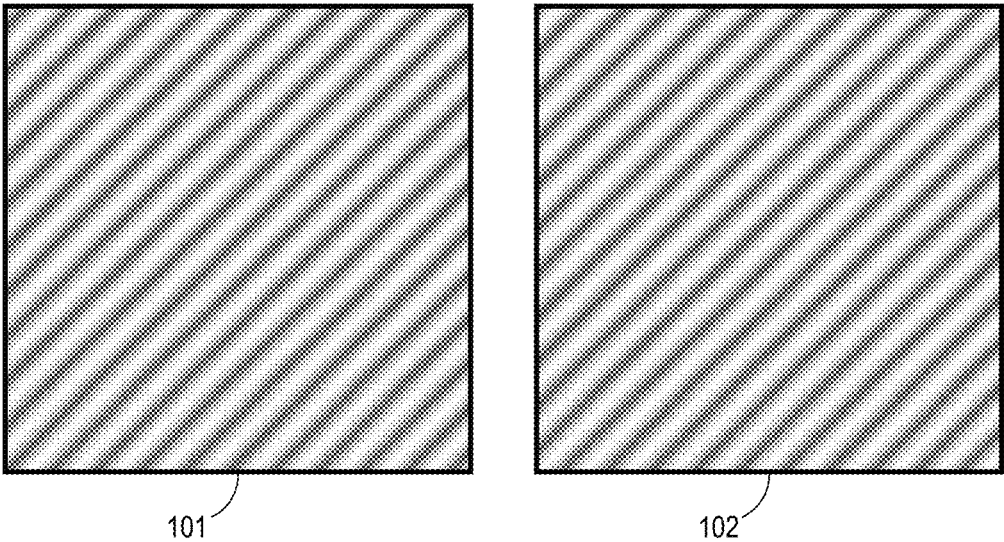*Primary Examiner* — Shervin Nakhjavan
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(57) **ABSTRACT**

A mobile electronic device is used to decode a printed correlation mark. The device receives an image of a printed correlation mark, identifies a decoding template, applies the template to detect hidden content within the printed correlation mark, and outputs an image of the detected hidden content on the display. The device may enhance the image before presenting it on the display.
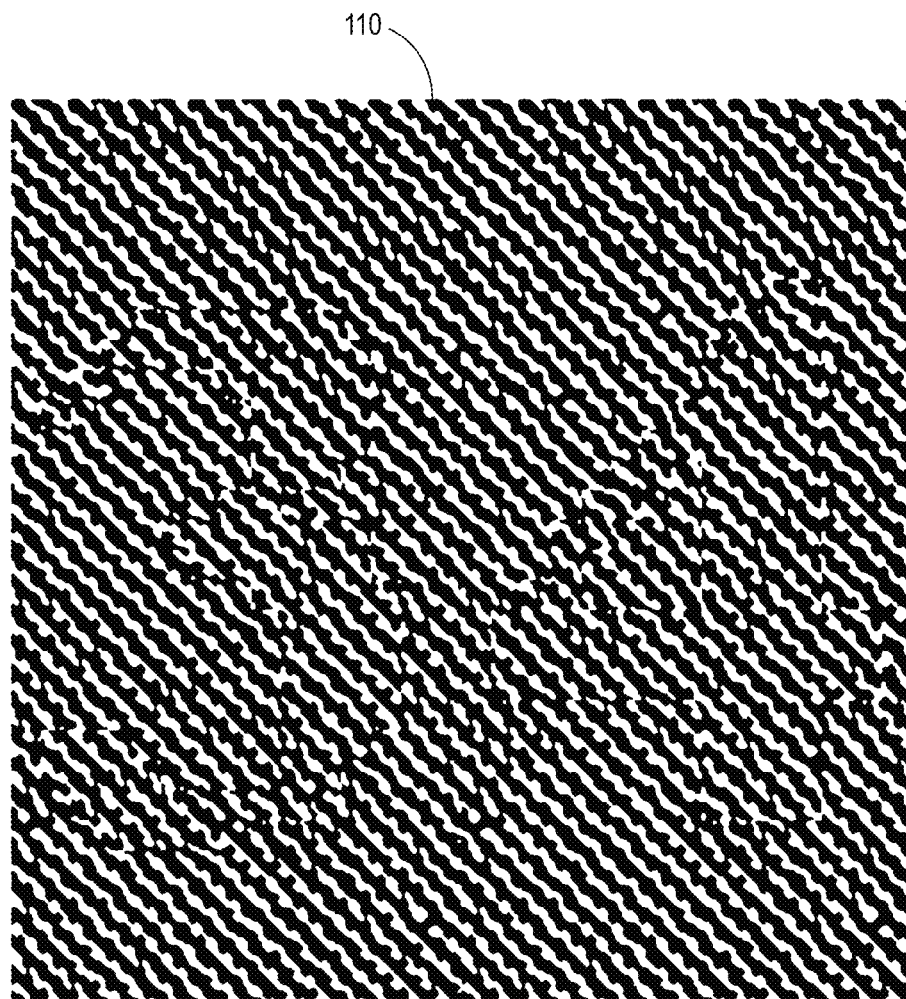
29 Claims, 7 Drawing Sheets

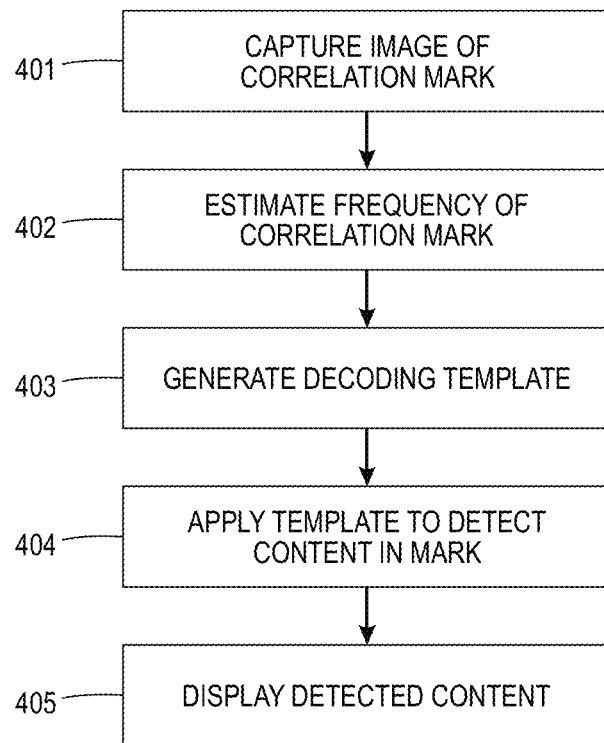401 — CAPTURE IMAGE OF CORRELATION MARK

402 — ESTIMATE FREQUENCY OF CORRELATION MARK

403 — GENERATE DECODING TEMPLATE

404 — APPLY TEMPLATE TO DETECT CONTENT IN MARK

405 — DISPLAY DETECTED CONTENT

101

FIG 1
PRIOR ART

101 102

FIG 2
PRIOR ART

110

FIG 3
PRIOR ART

401 — CAPTURE IMAGE OF CORRELATION MARK

402 — ESTIMATE FREQUENCY OF CORRELATION MARK

403 — GENERATE DECODING TEMPLATE

404 — APPLY TEMPLATE TO DETECT CONTENT IN MARK

405 — DISPLAY DETECTED CONTENT
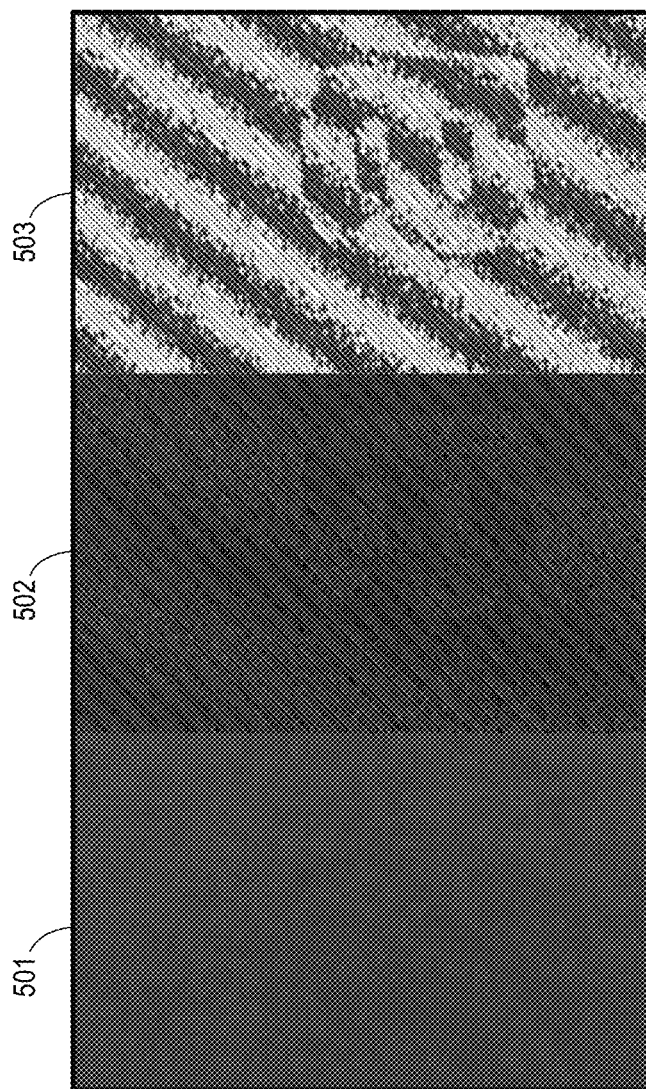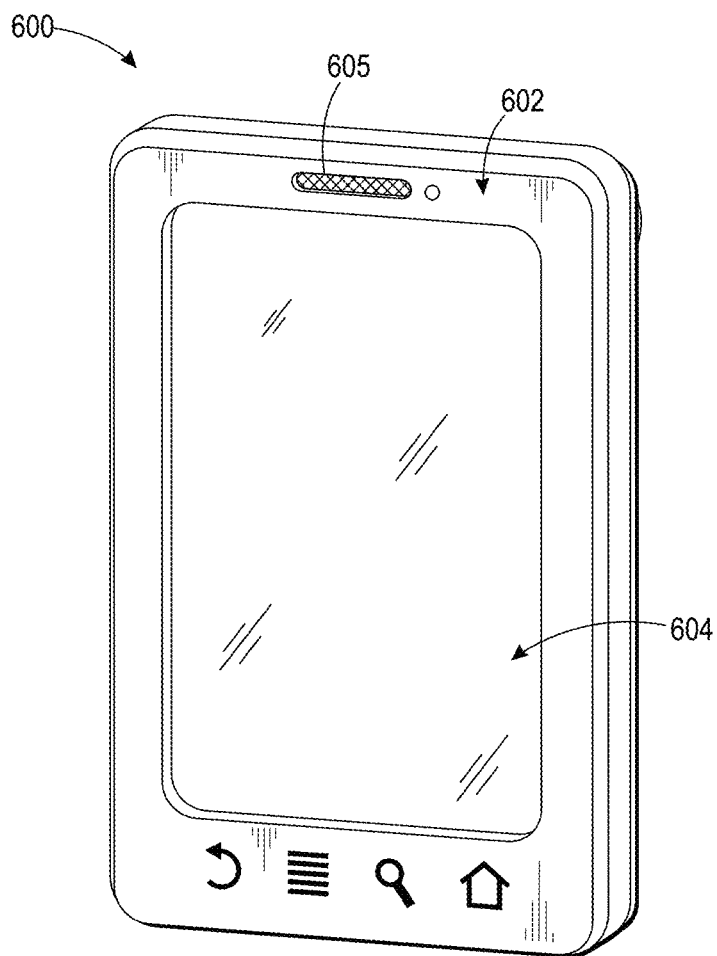
FIG 4
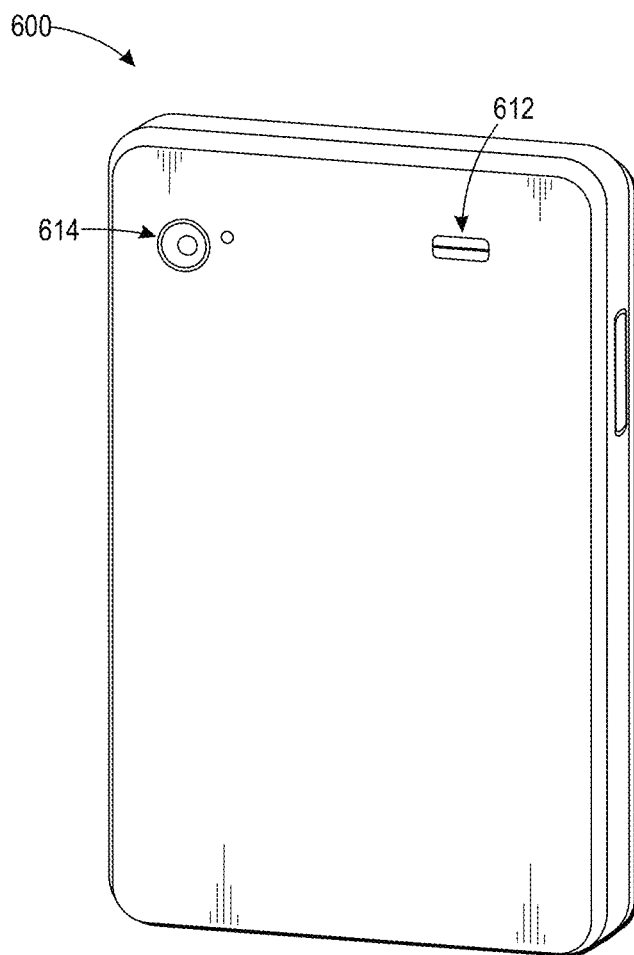
FIG 5

600

605

602

604
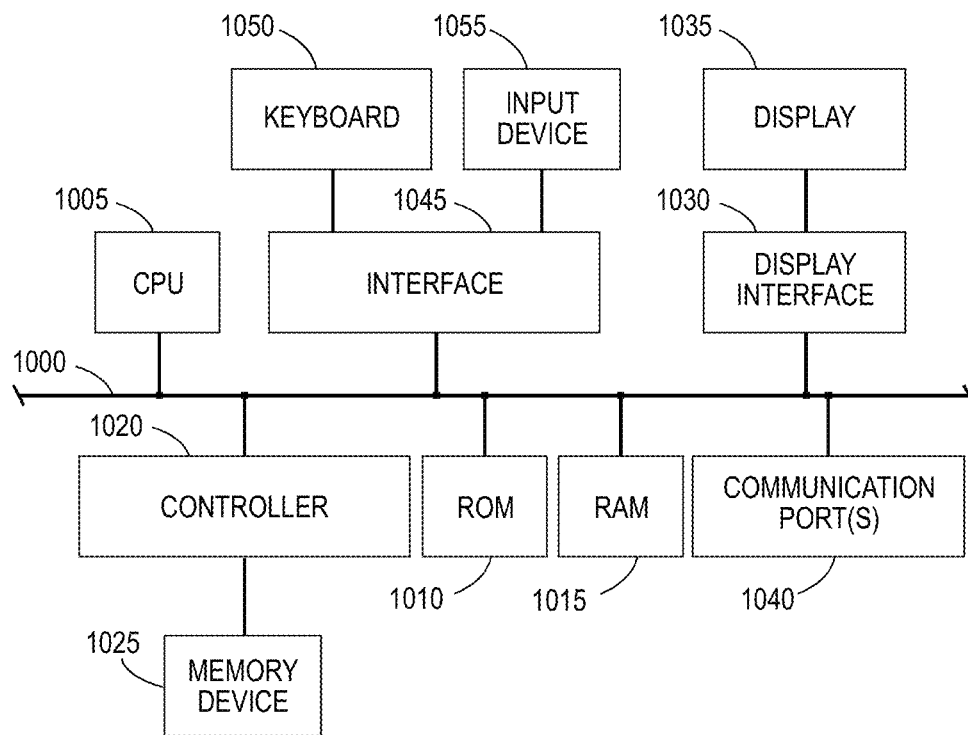
FIG 6A

600

612

614

FIG 6B

FIG 7

METHOD AND SYSTEM FOR VISUALIZING A CORRELATION MARK USING AN ELECTRONIC DEVICE

BACKGROUND

Security is an important requirement in many document production applications. In situations such as official or government document printing, event ticket printing, financial instrument printing and the like, many documents must be protected against copying, forging and/or counterfeiting. To do this, printed documents often include security marks that serve to prevent counterfeiting and/or identify a document as original.

A correlation mark is one example of a security mark. A correlation mark includes one or more elements that are invisible or hardly visible on a printed document. The hidden elements become visible when the document is viewed through a correlation mask that serves as a "key" to the correlation mark. An example of a correlation mark is taught in U.S. Pat. No. 5,734,752 to Knox, titled "Digital watermarking using stochastic screen." Other examples are disclosed in U.S. Pat. No. 7,894,626 to Wang et al., titled "System and method for the generation of multiple angle correlation-based digital watermarks," as well as in U.S. Pat. No. 7,894,626 to Wang et al., titled "System and method for the generation of multiple angle correlation-based digital watermarks" patterns." The disclosures of each of these references are fully incorporated herein by reference.

Although security markings such as correlation marks are effective on printed documents, they require a special device (a "screen" or "key") to decode them.

This document describes methods and systems for decoding a security mark that addresses at least some of the problems described above, and/or other problems.

SUMMARY

In an embodiment, an electronic device such as a mobile device is used to detect and display hidden content in a printed or otherwise displayed correlation mark. The device receives an image of the correlation mark, identifies a decoding template, applies the template to detect hidden content within the correlation mark, and outputs an image of the detected hidden content on a display.

When receiving the image, the device may use an image capture module (such as a camera) to capture the image. Alternatively, the device may receive the image as a data file from another source.

To identify the encoding template, the device may estimate a frequency of the correlation mark, and it may generate the decoding template using the frequency. Optionally, the device may enhance the image before presenting it on the display. Optionally, to estimate the frequency of the printed correlation mark the device may apply a two-dimensional discrete Fourier transform to the image and identify a peak location beyond a resulting main lobe of the transform as the frequency.

Optionally, to apply the template to detect hidden content, the device may high pass filter the captured image, multiply a result of the filtering by the template, repeat the multiplying any number times to yield a set of multiplied results, and select one of the multiplied results from the set as the best result. Optionally, when repeating the multiplication the device may do so on the template with a different relative shift as compared to previous instances of the multiplication.

Optionally, after applying the template, the device generating an enhanced the image of the detected hidden content. It may do so by, for example: (1) dividing the into non-overlapping blocks; (2) for each block, determining an average of an application of the template to pixels within the block; (3) assigning a value of 1 to each pixel in any block for which the determined average is positive; and (4) assigning a negative or zero value to each pixel in any block for which the determined average is negative or zero. Then, when causing the image of the detected hidden content to be presented on the display, the device may output the enhanced image.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1** and **2** represent a top "view" and a profile "view" of a pair of conjugate line screens that a computing device may use to create a correlation mark.

FIG. **3** is an enlarged example of a correlation mark of the prior art.

FIG. **4** is a flow diagram illustrating a process by which a mobile electronic device may decode a security mark.

FIG. **5** illustrates an example of a decoded correlation mark as displayed on an electronic display.

FIGS. **6A** and **6B** show an example of a mobile electronic device.

FIG. **7** is a block diagram showing various equipment that may be used to implement various embodiments of the processes described in this document.

DETAILED DESCRIPTION

This disclosure is not limited to the particular systems, devices and methods described, as these may vary. The terminology used in the description is for the purpose of describing the particular versions or embodiments only, and is not intended to limit the scope.

As used in this document, the singular forms of any word, and defining adjectives such as "a," "an" and "the," each include plural references unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. As used in this document, the term "comprising" means "including, but not limited to."

The term "security mark" refers to a marking made on a document that can be used to verify the authenticity of the document, and thus may help prevent counterfeiting or unauthorized duplication of the document. Examples of such marks include those known as correlation marks, which will be described in more detail below.

An "electronic device" is a device that includes a processor and non-transitory computer-readable memory. The memory contains programming instructions in the form of a software application that, when executed by the processor, causes the device to perform various operations according to the programming instructions. Examples of electronic devices include computers and servers, as well as mobile electronic devices such as smartphones, personal digital assistants, cameras, tablet devices, electronic readers, media players, satellite navigation devices and the like.

An "image capture module" refers to a software application and/or an image sensor device of an electronic device that is capable of optically viewing a scene and converting an interpretation of that scene into electronic signals so that the interpretation is saved to a digital image file comprising a still image.

The terms "memory" and "computer-readable medium" each refer to a non-transitory device on which computer-readable data, programming instructions or both may be stored. Unless the context specifically states that a single device is required or that multiple devices are required, the terms "memory" and "computer-readable medium" include both the singular and plural embodiments, as well as portions of such devices such as memory sectors.

A "processor" is a component of an electronic device that executes programming instructions. The term "processor" may refer to either a single processor or to multiple processors that together implement various steps of a process. Unless the context specifically states that a single processor is required or that multiple processors are required, the term "processor" includes both the singular and plural embodiments.

A correlation mark is a security mark containing one or more elements that are invisible or hardly visible on a printed document. These hidden elements become visible when the document is viewed through a correlation mask that serves as a "key" to the correlation mark. An example of a correlation mark is taught in U.S. Pat. No. 5,734,752 to Knox, titled "Digital watermarking using stochastic screen patterns," the disclosure of which is incorporated herein by reference in its entirety. Correlation marks typically require no special materials for the printing process. A correlation mark is typically robust, and can be copied by ordinary duplication methods.

Correlation marks can be detected either by scanning or capturing an image of a document containing the mark and processing the scanned/captured image, or by overlaying a transparency containing a "key" on top of the document to reveal the hidden watermark. A pattern printed onto a transparency is an example of such a transparency, which may be referred to as a correlation mask. The pattern in the mask may be a screen, such as a stochastic screen or line screen, that corresponds to pixel elements of mark. Aligning the correlation mask to the printed document or image causes a correlation image to become visible.

To generate a correlation mark, the system may retrieve and/or print a stochastic screen pattern and/or line screen pattern for the mark that is stored in a memory. Or, the system may generate a correlation mark by producing a first screen pattern for the foreground of the mark, and a second screen pattern for the background, using methods such as those described in U.S. Pat. No. 5,734,752.

The first and second screens may be conjugate line screens that are identical except with respect to their phase. For example, FIG. 1 illustrates a pair of line screens 101, 102 that are identical except in that the lines of the second screen 102 appear in a 180 degree phase shift with respect to the lines of the first screen 101. The view of FIG. 1 is a top view of each screen. FIG. 2 provides a profile view that can correspond to either of the screens 101, 102 of FIG. 1, as both screens share the same profile but have a different phase. When an electronic device generates a correlation mark using the screens, the mark's foreground and background will have similar average color and texture patterns, but will exhibit a different phase shift in texture. Thus, any characters hidden in the resulting mark will not be readily visible without the use of a key (a decoding device that includes a stochastic screen).

FIG. 3 shows an enlarged example of a correlation mark 110 that may be produced in accordance with the prior art. In this magnification, one who studies the mark closely may see the outlines of a mark containing the hidden characters "34." Typically, a correlation mark such as this would be

printed in a small, thumbnail size (such as about ¼ inch in height). When printed at a small size, the mark will appear to the human eye as substantially a constant gray pattern, and the hidden characters will not be visible without the use of a key. Note that while the mark 110 of FIG. 3 is printed as 100% black and white for the purpose of this illustration, it may be printed in shades of gray or color.

FIG. 4 is a flowchart illustrating various steps that may be used to decode the mark using a portable electronic device rather than a stochastic screen. First, a user may cause the device to capture an image of a correlation mark that is printed on a substrate (step 401). The device may capture this image via the image sensing module using any suitable software application, such as a camera application, a barcode scanning application, or a dedicated correlation mark detection application. Optionally, the device may detect a border of the correlation mark and output, via the display or audio output, a command or cue to move closer to or further away from the mark, or to adjust a position of the device so that the image is taken from directly over the mark rather than at an angle with respect to the mark. Examples of such processes and visual cues are disclosed in U.S. patent application Ser. No. 13/968,534, filed by Bala, titled "Mobile Document Capture Assist for Optimized Text Recognition," as well as in U.S. Patent Application Pub. No. 2013/0140356, filed by Fan et al., titled "Camera Positioning Tool for Symbology Reading," the disclosures of which are fully incorporated herein by reference.

By executing programming instructions, the device's processor (or a processor that receives the image from the device) may estimate a frequency of the printed correlation mark (step 402). The processor may do this using a two-dimensional Fourier method, such as those which are now or hereafter known in the art to convert spatial domain image data into the frequency domain. This process may identify an image having a set of rows and a set of columns, and it may return a two-dimensional FFT of each column in the matrix by applying a two-dimensional FFT to the image. For line screens, this may be simplified using two one-dimensional discrete Fourier transforms (DFTs), one on the vertical direction and one in the horizontal direction. The peak locations beyond the main lobe will reveal the screen frequency.

The processor may then generate a decoding template (step 403) using the estimated frequency. The template will comprise a periodic pattern that bears the same frequency as the detected screen frequency. The template may be static, or dynamic in that it changes as the screen pattern changes. For example, in some embodiments, the template may comprise a sinusoid that bears the same frequency as the detected screen frequency. Specifically, the template t(x,y) may be generated as:

$$t(x,y)=\sin[2\pi(xP_x+yP_y)],$$

where P_x and P_y are the x and y components of the detected screen period, respectively. The processor may then apply the template to the captured image to detect hidden content within the printed correlation mark (step 404). For example, the system may apply a template matching process by high pass filtering the captured image in the spatial or frequency domain, and then multiply the result of the filtering process by the template. The processor may shift the template any number (N) of times, each with an evenly spaced shift from 0 degrees to 180 degrees, and then repeat the multiplication. For each iteration k, E_k, the processor may determine the total energy of the resulting image as:

$$E_k=\Sigma f_k(x,y)^2$$

where $f_k(x, y)$ is the matching result for the kth iteration:

$$f_k(x, y) = i(x, y)t\left(x + \frac{kP_x}{2N}, y\right) \quad \text{if } T_x \neq 0$$

$$= i(x, y)t\left(x, y + \frac{kP_y}{2N}\right) \quad \text{if } T_x = 0$$

where $t(x, y)$ and $i(x, y)$ are the values of the template t and image i after high pass filtering, respectively. The iteration with the maximum E_k, may be considered the best iteration, and its result may adopted as the result for an image that displays hidden content within the correlation mark.

The brightness and contrast of the resulting image can be further examined to see if the image appears too dark or has insufficient contrast. In some embodiments, the brightness of the image may be determined as a mean, median, average or mode of each of the pixel brightness values in the image. If the image exhibits a brightness that is below a threshold or has a contrast that is below a threshold, the processor may further enhance the resulting image by dividing it into non-overlapping blocks, each covering one or more screen periods.

To perform the enhancement, for each block, the processor may determine an average of the matching result, specifically the average value of $f_{kmax}(x, y)$, where k_{max} is the iteration with the maximum energy E_k. Then, the system may output a contrast-enhanced image by assigning a value of 1 to each pixel in a block where the matching average is positive. Otherwise, for each block having a matching average that is negative or zero, the system may set the value of each pixel in the block to zero or a negative value (e.g., -1).

Finally, the processor will cause output the detected hidden content on the display (step **405**). An example of this is shown in FIG. **5**, which illustrates presents a captured image **501** before the decoding process starts, a detection result after processing but before enhancement **502**, and an enhanced image **503** revealing the letter "a" as hidden content.

FIG. **6A** shows a front view of an example of a mobile electronic device, generally designated **600**. The mobile electronic device **600** may include a front face **602** and a display **604**. The display **604** may be any suitable component for displaying images, such as, but not limited to, an electroluminescent display, electronic paper display, light emitting diode (LED) display, liquid crystal (LCD) display, plasma display panel, digital light processing (DLP) display, and organic light-emitting diode (OLED) display. The display **604** may further include a touch sensitive screen, such as, but not limited to, resistive touchscreens, capacitive touchscreens, and infrared touchscreens. The device also may include an audio output **605** such as a speaker.

FIG. **6B** shows a rear face **612** of the mobile electronic device **600**. The rear face **612** may include an image capture device **614**. The image capture device **614** may be any suitable component capable of receiving an optical image and transmitting the information to other components for processing.

While the image capture device **614** is depicted on the rear face of the present example, persons skilled in the art will appreciate that the image capture device **614** may be positioned at any location upon any face of the mobile device **600**, or it may even be external to the mobile device **600** and connected by any means of electronic communication, such

as, but not limited to, physical cable communication such as universal serial bus (USB), wireless radio communication, wireless light communication, or near field communication technology.

FIG. **7** depicts a block diagram of various hardware that may be used to contain or implement the various computer processes and systems as discussed above. For example, the electronic device **600** of FIGS. **6A** and **6B** may contain elements such as those shown in FIG. **7**. An electrical bus **1000** serves as the main information highway interconnecting the other illustrated components of the hardware. CPU **1005** is the central processing unit of the system, representing a processor (which may be a single processing device or multiple processing devices) performing calculations and logic operations required to execute a program. CPU **1005**, alone or in conjunction with one or more of the other elements disclosed in FIG. **7**, is a processing device, computing device or processor as such terms are used within this disclosure. Read only memory (ROM) **1010** and random access memory (RAM) **1015** constitute examples of memory devices.

A controller **1020** interfaces with one or more optional memory devices **1025** to the system bus **1000**. These memory devices **1025** may include, for example, an external or internal DVD drive, a CD ROM drive, a hard drive, flash memory, a USB drive or the like. As indicated previously, these various drives and controllers are optional devices. Additionally, the memory devices **1025** may be configured to include individual files for storing any software modules or instructions, auxiliary data, incident data, common files for storing groups of contingency tables and/or regression models, or one or more databases for storing the information as discussed above.

Program instructions, software or interactive modules for performing any of the functional steps associated with the processes as described above may be stored in the ROM **1010** the RAM **1015**, and/or any other non-transitory computer-readable medium. Optionally, the program instructions may be stored on a computer readable medium such as a compact disk, a digital disk, flash memory, a memory card, a USB drive, an optical disc storage medium, a distributed storage medium such as a cloud-based architecture, and/or other recording medium.

A display interface **1030** may permit information to be displayed on the display **1035** in audio, visual, graphic or alphanumeric format. For example, the correlation mark or decoded data discussed above may be output on the display **1035**. Communication with external devices may occur using various communication ports **1040**. A communication port **1040** may be attached to a communications network, such as the Internet or a local area network.

The hardware may also include an interface **1045** which allows for receipt of data from input devices such as a keyboard **1050** or other input device **1055** such as a mouse, a joystick, a touch screen, a remote control, a pointing device, a video input device and/or an audio input device. The image sensing device described in FIGS. **6A** and **6B** also may be an example of an input device **1055**.

The features and functions disclosed above, as well as alternatives, may be combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations or improvements may be made by those skilled in the art, each of which is also intended to be encompassed by the disclosed embodiments.

The invention claimed is:

1. A mobile electronic device configured to capture and display hidden data in a correlation mark, the device comprising:

a processor;

a display;

an image capture module; and

a computer-readable memory containing programming instructions that, when executed, cause the processor to:

receive, via the image capture module, an image of a printed correlation mark;

identify a dynamic decoding template, wherein a frequency of the dynamic decoding template changes as the image of the printed correlation mark changes;

apply the template to detect hidden content within the printed correlation mark; and

output an image of the detected hidden content on the display.

2. The device of claim 1, further comprising additional programming instructions that, when executed, cause the processor to:

estimate a frequency of the printed correlation mark; and

to identify the decoding template, generate the decoding template using the frequency.

3. The device of claim 2, wherein the instructions to estimate a frequency of the printed correlation mark comprise instructions to:

apply a two-dimensional discrete Fourier transform to the image; and

identify a peak location beyond a resulting main lobe of the transform as the frequency.

4. The device of claim 1, wherein the instructions to apply the template to detect hidden content comprise instructions to:

high pass filter the captured image and then multiply a result of the filtering by the template;

repeat the step of multiplying the result of the filtering by the template a plurality of times to yield a plurality of multiplied results; and

select one of the multiplied results as a best result.

5. The device of claim 4, wherein the instructions to repeat the step of multiplying the result of the filtering by the template a plurality of times to yield a plurality of multiplied results comprise, for each step of multiplying, performing the multiplying on the template with a different relative shift.

6. The device of claim 1, further comprising additional programming to, after applying the template:

generate an enhanced image of the detected hidden content by:

dividing the image into non-overlapping blocks,

for each block, determining an average of an application of the template to pixels within the block,

assigning a value of 1 to each pixel in any block for which the determined average is positive, and

assigning a negative or zero value to each pixel in any block for which the determined average is negative or zero; and

when outputting the image of the detected hidden content on the display, outputting the enhanced image.

7. A method of capturing and displaying hidden data in a correlation mark, the method comprising:

by a processor of an electronic device:

receiving an image of a correlation mark;

identifying a dynamic decoding template, wherein a frequency of the dynamic decoding template changes as the image of the printed correlation mark changes;

applying the template to detect hidden content within the correlation mark;

generating an image comprising the detected hidden content; and

causing the image with the detected hidden content to be presented on a display of the electronic device.

8. The method of claim 7, further comprising:

by an image capture module of the electronic device, capturing the image of the printed correlation mark.

9. The method of claim 7:

further comprising, by the processor, estimating a frequency of the correlation mark; and

wherein identifying the decoding template comprises generating the decoding template using the frequency.

10. The method of claim 9, wherein estimating the frequency of the correlation mark comprises:

applying a two-dimensional discrete Fourier transform to the image; and

identifying a peak location beyond a resulting main lobe of the transform as the frequency.

11. The method of claim 7, wherein applying the template to detect hidden content comprises:

high pass filtering the captured image:

multiplying a result of the filtering by the template;

repeating the multiplying a plurality of times to yield a plurality of multiplied results; and

selecting one of the multiplied results as a best result.

12. The method of claim 11, wherein repeating the multiplying a plurality of times to yield a plurality of multiplied results comprises, for each instance of the multiplying, performing the multiplying on the template with a different relative shift.

13. The method of claim 7, further comprising, by the processor:

after applying the template, generating an enhanced image of the detected hidden content by:

dividing the image into non-overlapping blocks,

for each block, determining an average of an application of the template to pixels within the block,

assigning a value of 1 to each pixel in any block for which the determined average is positive, and

assigning a negative or zero value to each pixel in any block for which the determined average is negative or zero; and

when causing the image with the detected hidden content to be presented on the display, outputting the enhanced image.

14. A non-transitory computer-readable medium containing programming instructions configured to, when executed, cause a processor of an electronic device to:

receive an image of a correlation mark;

identify a dynamic decoding template, wherein the dynamic decoding template changes as the image of the printed correlation mark changes;

apply the template to detect hidden content within the correlation mark;

generate an image comprising the detected hidden content; and

cause the image with the detected hidden content to be presented on a display of the electronic device.

15. The computer-readable medium of claim 14, wherein the instructions further comprise instructions to cause an image capture module of the electronic device to capture the image of the correlation mark.

16. The computer-readable medium of claim 14, wherein: the instructions further comprise instructions to estimate a frequency of the printed correlation mark; and the instructions to identify the decoding template comprise instructions to generate the decoding template using the frequency.

17. The computer-readable medium of claim 16, wherein the instructions to estimate the frequency of the printed correlation mark comprise instructions to:

apply a two-dimensional discrete Fourier transform to the image; and

identify a peak location beyond a resulting main lobe of the transform as the frequency.

18. The computer-readable medium of claim 14, wherein the instructions to apply the template to detect hidden content comprise instructions to:

high pass filter the captured image:

multiply a result of the filtering by the template;

repeat the multiplying a plurality of times to yield a plurality of multiplied results; and

select one of the multiplied results as a best result.

19. The computer-readable medium of claim 18, wherein the instructions to repeat the multiplying a plurality of times to yield a plurality of multiplied results comprise instructions to, for each instance of multiplying, perform the multiplying on the template with a different relative shift.

20. The computer-readable medium of claim 14, further comprising:

instructions to, after applying the template, generate an enhanced image of the detected hidden content by:

divide the image into non-overlapping blocks,

for each block, determine an average of an application of the template to pixels within the block,

assign a value of 1 to each pixel in any block for which the determined average is positive, and

assign a negative or zero value to each pixel in any block for which the determined average is negative or zero,

instructions to output the enhanced image when causing the image of the detected hidden content to be presented on the display.

21. A mobile electronic device configured to capture and display hidden data in a correlation mark, the device comprising:

a processor;

a display;

an image capture module; and

a computer-readable memory containing programming instructions that, when executed, cause the processor to:

receive, via the image capture module, an image of a printed correlation mark;

identify a decoding template;

apply the template to detect hidden content within the printed correlation mark by:

high pass filtering the captured image and then multiplying a result of the filtering by the template,

repeating the step of multiplying the result of the filtering by the template a plurality of times to yield a plurality of multiplied results, and

selecting one of the multiplied results as a best result; and

output an image of the detected hidden content on the display.

22. The device of claim 21, wherein the instructions to repeat the step of multiplying the result of the filtering by the template a plurality of times to yield a plurality of multiplied results comprise, for each step of multiplying, performing the multiplying on the template with a different relative shift.

23. A method of capturing and displaying hidden data in a correlation mark, the method comprising:

by a processor of an electronic device:

receiving an image of a correlation mark;

identifying a decoding template;

applying the template to detect hidden content within the correlation mark by:

high pass filtering the captured image,

multiplying a result of the filtering by the template,

repeating the multiplying a plurality of times to yield a plurality of multiplied results, and

selecting one of the multiplied results as a best result;

generating an image comprising the detected hidden content; and

causing the image with the detected hidden content to be presented on a display of the electronic device.

24. The method of claim 23, wherein repeating the multiplying a plurality of times to yield a plurality of multiplied results comprises, for each instance of the multiplying, performing the multiplying on the template with a different relative shift.

25. A non-transitory computer-readable medium containing programming instructions configured to, when executed, cause a processor of an electronic device to:

receive an image of a correlation mark;

identify a decoding template;

apply the template to detect hidden content within the correlation mark;

generate an image comprising the detected hidden content by:

high pass filtering the captured image,

multiplying a result of the filtering by the template,

repeat the multiplying a plurality of times to yield a plurality of multiplied results, and

selecting one of the multiplied results as a best result; and

cause the image with the detected hidden content to be presented on a display of the electronic device.

26. The computer-readable medium of claim 25, wherein the instructions to repeat the multiplying a plurality of times to yield a plurality of multiplied results comprise instructions to, for each instance of multiplying, perform the multiplying on the template with a different relative shift.

27. A mobile electronic device configured to capture and display hidden data in a correlation mark, the device comprising:

a processor;

a display;

an image capture module; and

a computer-readable memory containing programming instructions that, when executed, cause the processor to:

receive, via the image capture module, an image of a printed correlation mark;

identify a decoding template;

apply the template to detect hidden content within the printed correlation mark;

generate an enhanced image of the detected hidden content by:

dividing the image into non-overlapping blocks,

for each block, determining an average of an application of the template to pixels within the block,

assigning a value of 1 to each pixel in any block for which the determined average is positive, and

assigning a negative or zero value to each pixel in any block for which the determined average is negative or zero; and

output the enhanced image of the detected hidden content on the display.

28. A method of capturing and displaying hidden data in a correlation mark, the method comprising:

by a processor of an electronic device:

receiving an image of a correlation mark;

identifying a decoding template;

applying the template to detect hidden content within the correlation mark;

generating an enhanced image of the detected hidden content by:

dividing the image into non-overlapping blocks,

for each block, determining an average of an application of the template to pixels within the block,

assigning a value of 1 to each pixel in any block for which the determined average is positive, and

assigning a negative or zero value to each pixel in any block for which the determined average is negative or zero; and

causing the enhanced image with the detected hidden content to be presented on a display of the electronic device.

29. A non-transitory computer-readable medium containing programming instructions configured to, when executed, cause a processor of an electronic device to:

receive an image of a correlation mark;

identify a decoding template;

apply the template to detect hidden content within the correlation mark;

generate an enhanced image of the detected hidden content by:

dividing the into non-overlapping blocks,

for each block, determining an average of an application of the template to pixels within the block,

assigning a value of 1 to each pixel in any block for which the determined average is positive, and

assigning a negative or zero value to each pixel in any block for which the determined average is negative or zero; and

cause the enhanced image with the detected hidden content to be presented on a display of the electronic device.

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